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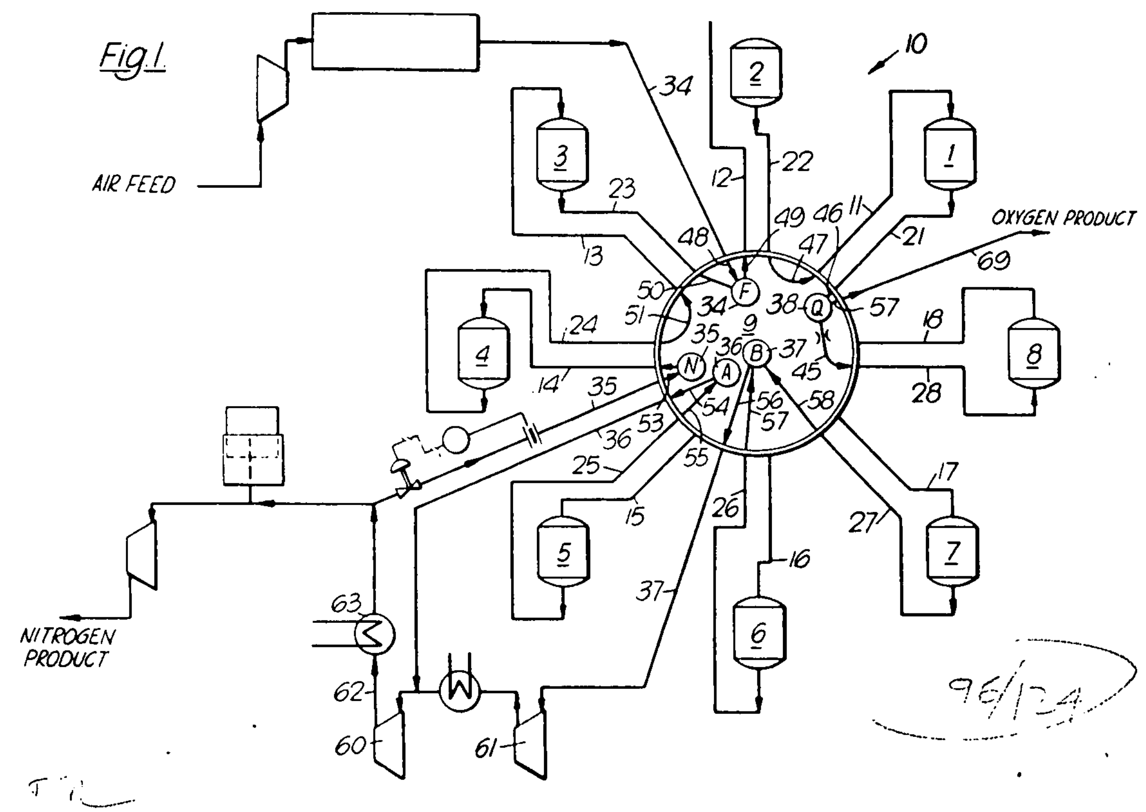
(54) Separating oxygen and nitrogen from air by adsorption

(57) Apparatus for separating oxygen and nitrogen from air comprises a plurality of vessels 1–8 containing molecular sieve, a rotary valve 9, an air supply line 34 connected to the rotary valve, means for directing air from the rotary valve to at least first and second of said vessels arranged in series, and means for rotating the rotary valve so that, in use, the molecular sieve in the first vessel is saturated and the molecular sieve in the second vessel is unsaturated when the rotary valve moves to direct air through the second and third vessels in series. Each molecular sieve bed is consequently used until fully saturated. The rotary valve 9 may also connect the saturated beds sequentially with a line 35 carrying flushing nitrogen, a first suction line 36, a second suction line 37 effective to produce a lower pressure than the first suction line, and a product repressurising line 45.

Fig.1.



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The drawings originally filed were informal and the print here reproduced is taken from a later filed formal copy.

SPECIFICATION

Apparatus for separating oxygen and nitrogen from air

This invention relates to an apparatus for separating oxygen and nitrogen from air.

A large number of schemes have been proposed for separating oxygen and nitrogen from air using molecular sieves. Each of these schemes has one notable disadvantage, viz regeneration must be started before the molecular sieve material is fully saturated. Thus, in a typical air separation plant using C&A molecular sieves which adsorbs nitrogen preferentially, breakthrough of substantial quantities of nitrogen occurs when only 85 to 90% of the sieve is saturated. Since both the under utilised part of the molecular sieve and the saturated part are subjected to regeneration a certain amount of energy is wasted in attempting to regenerate the under utilised molecular sieve.

It is an object of at least preferred embodiments of the present invention to provide an apparatus which, when correctly operated, will reduce this loss of energy.

According to the present invention there is provided an apparatus for separating oxygen and nitrogen from air, which apparatus comprises a plurality of vessels containing molecular sieve, a rotary valve, an air supply line connected to said rotary valve, means for directing air from said rotary valve to at least first and second of said vessels arranged in series, and means for rotating said rotary valve so that, in use, the molecular sieve in said first vessel is saturated and the molecular sieve in said second vessel is unsaturated when said rotary valve moves to direct air through said second and a third vessel in series.

In practice, the saturated molecular sieve will contain nitrogen with a small amount of oxygen. In order to reduce the quantity of this oxygen to an acceptable level, the rotary valve is preferably provided with means to direct nitrogen through the first vessel to rinse oxygen therefrom while air is passing through said second and third vessels. Advantageously, such rinsing is effected by passing nitrogen through said first vessel and said second vessel in series after said second vessel is saturated and said rotary valve has moved to direct air through said third and fourth vessel in series.

Although the molecular sieve may be regenerated by heat, this is not recommended since heat transfer from one stream to another within the rotary valve can upset the operation of the apparatus. Accordingly, it is advantageous for the rotary valve to include means for evacuating the first vessel, either after it is saturated with nitrogen and oxygen, or after rinsing if reasonably pure nitrogen is required. Advantageously, such evacuation is carried out in two consecutive steps at progressively lower pressures.

If regeneration is carried out at a lower pressure than adsorption then, in order to complete the cycle, the rotary valve is preferably provided with means for directing product oxygen to said first vessel to re-pressurise it immediately prior to said rotary valve moving to place said first vessel on adsorption.

In order to reduce wastage in the pipes connecting the vessels to the rotary valve the vessels are preferably arranged circumjacent the rotary valve.

In a preferred embodiment eight vessels are arranged circumjacent a rotary valve. Two vessels are connected in series to a supply of air via said rotary valve, two vessels are connected in series to a source of nitrogen for rinsing via said rotary valve, one vessel is connected to a low pressure source via said valve, two vessels are connected to a very low pressure source via said rotary valve, and one vessel is connected via said rotary valve to a source of product oxygen to repressurise said vessel.

For a better understanding of the present invention, reference will now be made, by way of example, to the accompanying drawings in which:

Figure 1 is a schematic flowsheet of an apparatus in accordance with the present invention;

Figure 2 is a top plan view of a multiport valve forming part of the apparatus shown in Fig. 1;

Figure 3 is a side elevation of the multiport; and

Figure 4 is a bottom plan view of the multiport valve.

Referring to Fig. 1, there is shown an apparatus for separating oxygen and nitrogen from air. The apparatus, which is generally identified by reference numeral 10, comprises eight identical vessels 1 to 8 arranged circumjacent a multiport valve 9. Each of vessels 1 to 8 contains 5A molecular sieve and is provided with a respective inlet conduit 11 to 18 and a respective outlet conduit 21 to 28.

As shown in Figs. 2 to 4, the multiport valve 9 comprises a base plate 31, a top plate 32 and a rotatable core 33. The inlet and outlet conduits 11 to 18 and 21 to 28 are connected to the base plate 31 as shown in Fig. 4.

An air supply line 34, nitrogen rinse line 35, low vacuum line 36, high vacuum line 37, and oxygen product line 38 are connected to the top plate 32. The core 33 comprises an upper disc 68 and a lower disc 39. The upper surface of the upper disc 68 is provided with a cylindrical channel 40 and four annular channels 41, 42, 43 and 44, which remain in constant communication with line 37, 36, 35, 34 and 38 respectively. A

plurality of conduits 45 to 56 connect the four annular channels 41, 42, 43 and 44 to holes in the lower disc 39.

As the core 33 rotates clockwise with respect to the base plate 31 and top plate 32, inlet conduits 11 to 18 are brought successively into contact with lines 34 and 35 and the outlet conduits 21 to 28 are brought successively into contact with lines 36, 37 and 38.

In operation core 33 rotates once every 6 minutes.

In the position shown in Fig. 1, vessels 1 and 2 are receiving dry, carbon dioxide free air at 20 psia from air supply line 34. The air enters the multiport valve 9 through air supply line 34, passes through conduits 48 and 49 in core 33 and enters vessel 2 via inlet conduit 12. The molecular sieve in vessel 2 adsorbs a large proportion of nitrogen from the air together with a small amount of oxygen. The unadsorbed gas leaving vessel 2 through outlet conduit 22, passes through conduit 47 in core 33 and enters vessel 1 via inlet conduit 11. The molecular sieve in vessel 1 adsorbs a majority of the remaining nitrogen whilst the oxygen, together with unadsorbed nitrogen is returned to the core 33 via outlet pipe 21. The gas enters the core 33 through conduit 46 and the major portion thereof passes through conduit 57 to oxygen product line 69.

At intervals of 45 seconds the core 33 rotates clockwise 45° so that each vessel moves anti-clockwise relative to the core 33. Thus, after an initial period of 45 seconds, vessel 1 occupies the position of vessel 2, vessel 2 occupies the position of vessel 3 and so on. It will be recalled that the molecular sieve in vessel 2 contained some oxygen. This is removed in two stages by passing pure nitrogen sequentially through the vessels. In particular, pure nitrogen is introduced into the multiport valve 9 through nitrogen rinse line 35. The nitrogen passes through conduits 53 and 52 in core 33 and enters vessel 4 via inlet conduit 14. The nitrogen displaces substantially all the oxygen from the molecular sieve and the resulting gas is returned to the core 33 via outlet conduit 24 before being returned to vessel 3 via conduit 51 and inlet conduit 13. The gas leaving vessel 3 has a composition close to that of air and is introduced into conduit 50 to supplement the air feed.

Once the molecular sieve is substantially oxygen free, the nitrogen can be obtained as product by subjecting the sieve to vacuum. In particular, vessel 5 is reduced to a pressure of about 3 psia by vacuum pump 60 which communicates with vessel 5 via outlet conduit 25, conduits 55 and 54, and low vacuum line 36. Vessels 6 and 7 are reduced to a pressure of about 0.6 psia by vacuum pump 61 which communicates with vessels 6 and 7 via outlet conduits 26 and 27, conduits 57, 58, 56 and high vacuum line 37. Both vacuum pumps 60 and 61 discharge the nitrogen removed from vessels 5, 6 and 7 into a line 62. The nitrogen in line 62 is cooled in heat exchanger 63 and the major proportion of the nitrogen is compressed and sent to storage. The minor portion is metered along nitrogen rinse line 35.

After evacuation is complete, repressurisation occurs. As shown, vessel 8 is being repressurised with product oxygen from the conduit 46 and 45. The flow of oxygen into vessel 8 is restricted by a capillary tube 63.

Typically, the oxygen leaving oxygen product line 38 is 92% (by volume) pure.

Various modification to the apparatus described with reference to the drawings can be made, for example the 5 A molecular sieve could be replaced by sodium mordenite. Alternatively, the 5 A molecular sieve could be replaced by a carbon molecular sieve in which case oxygen would be adsorbed in vessels 1 and 2. Rinsing (vessels 3 and 4) could be dispensed with, and repressurizing (vessel 8) could be effected by nitrogen.

CLAIMS

1. An apparatus for separating oxygen and nitrogen from air, which apparatus comprises a plurality of vessels containing molecular sieve, a rotary valve, an air supply line connected to said rotary valve, means for directing air from said rotary valve to at least first and second of said vessels arranged in series, and means for rotating said rotary valve so that, in use, the molecular sieve in said first vessel is saturated and the molecular sieve in said second vessel is unsaturated when said rotary valve moves to direct air through said second and a third vessel in series.

2. An apparatus as claimed in Claim 1, wherein said rotary valve includes means to direct nitrogen through said first vessel whilst air is passing through said second and third vessels.

3. An apparatus as claimed in Claim 2, wherein said rotary valve includes means to direct nitrogen through said first and second vessels in series when said rotary valve is moved to direct air through said third and fourth vessel in series.

4. An apparatus as claimed in Claim 1, wherein said rotary valve includes means for evacuating the first vessel after it is saturated.

5. An apparatus as claimed in Claim 2 or 3, wherein said rotary valve includes means to evacuate said first vessel after it has been rinsed with nitrogen.

6. An apparatus as claimed in Claim 4 or 5, including means to repressurize a vessel with product oxygen after said vessel has been evacuated.

7. An apparatus for separating oxygen

and nitrogen from air substantially as hereinbefore described with reference to and as shown in the accompanying drawing.

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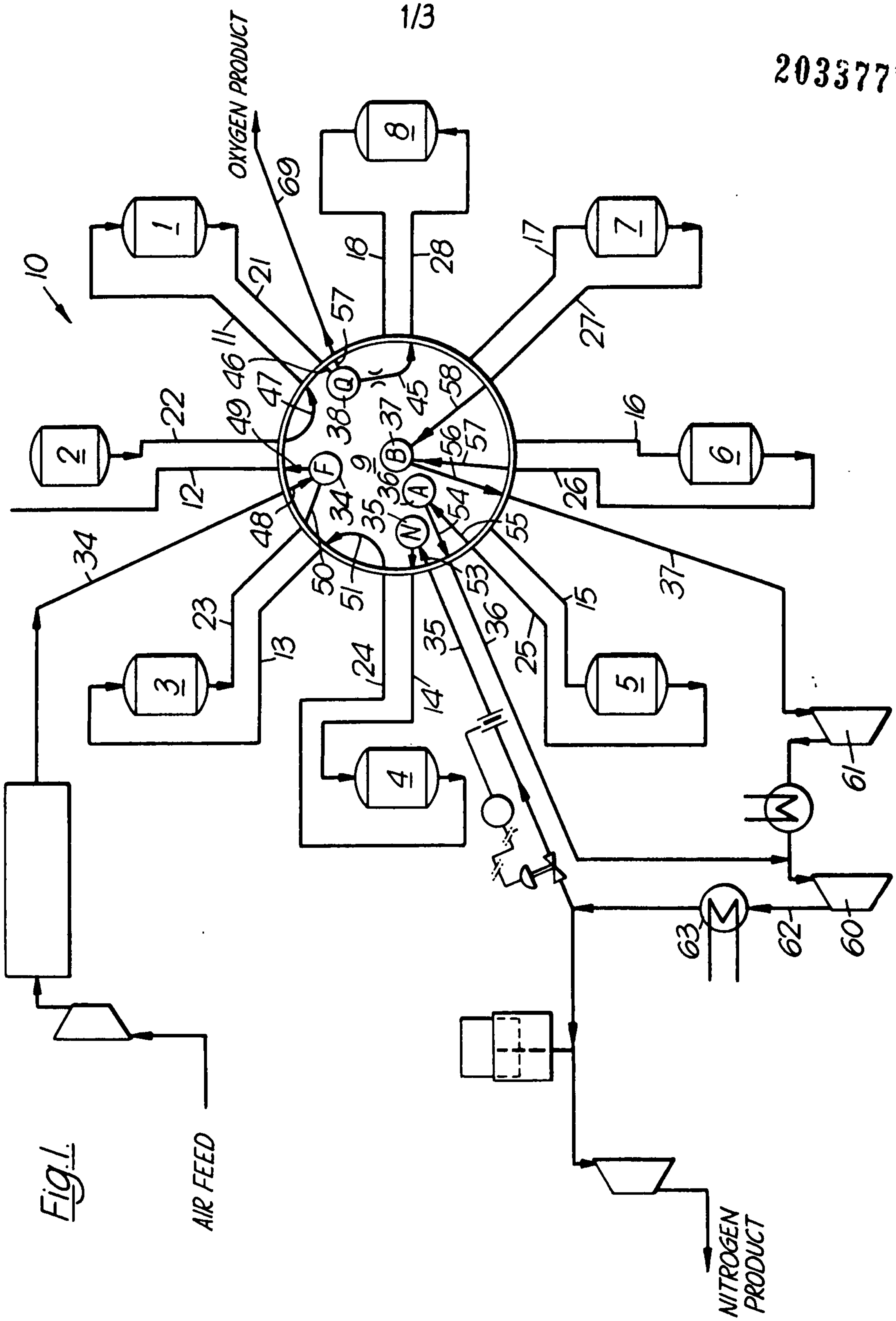

Fig.1.

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Fig. 2.

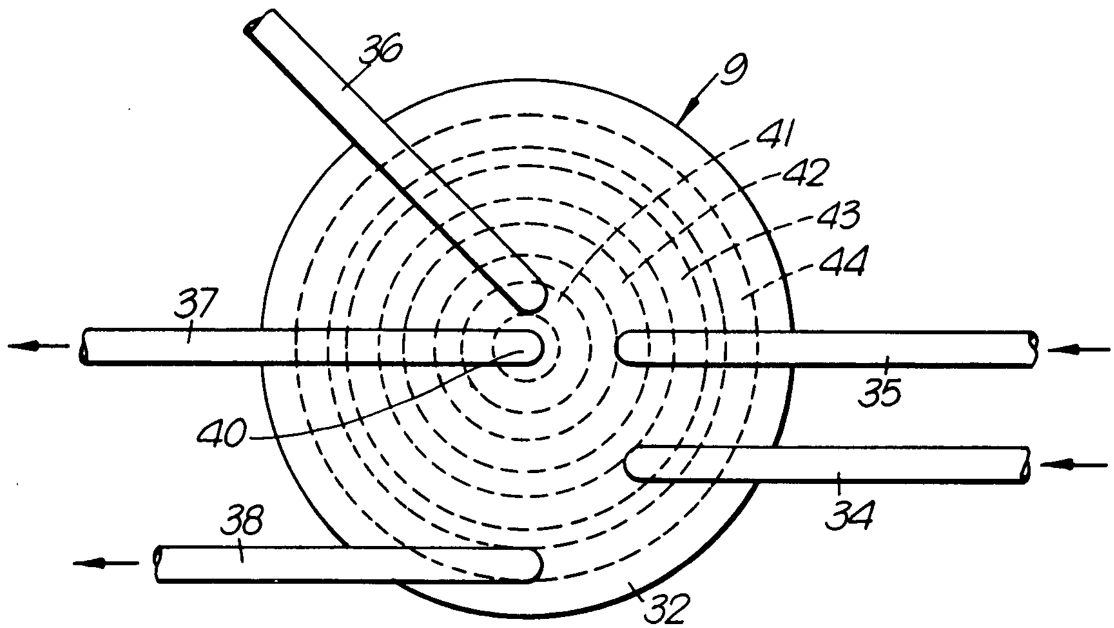

Fig. 3.

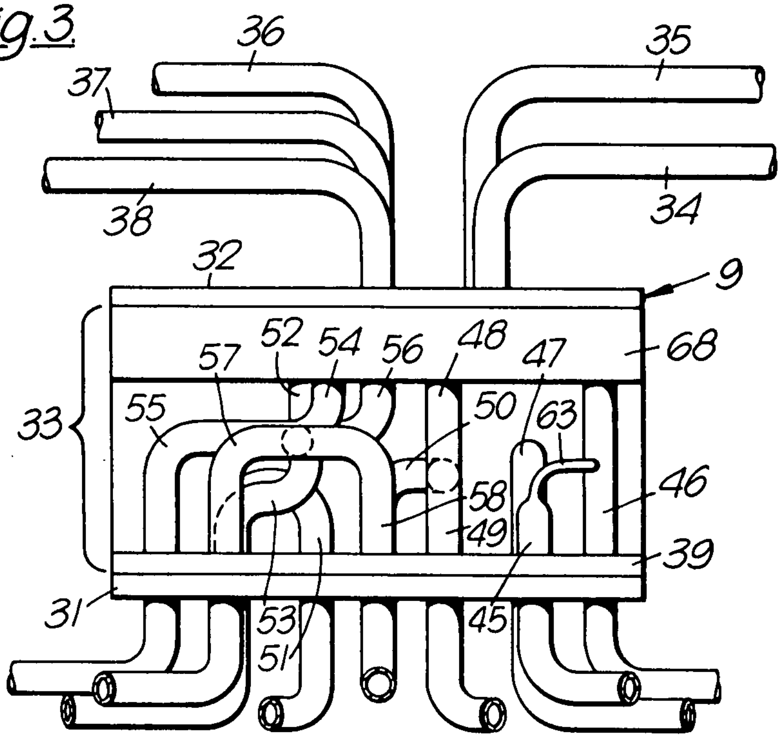

Fig.4.